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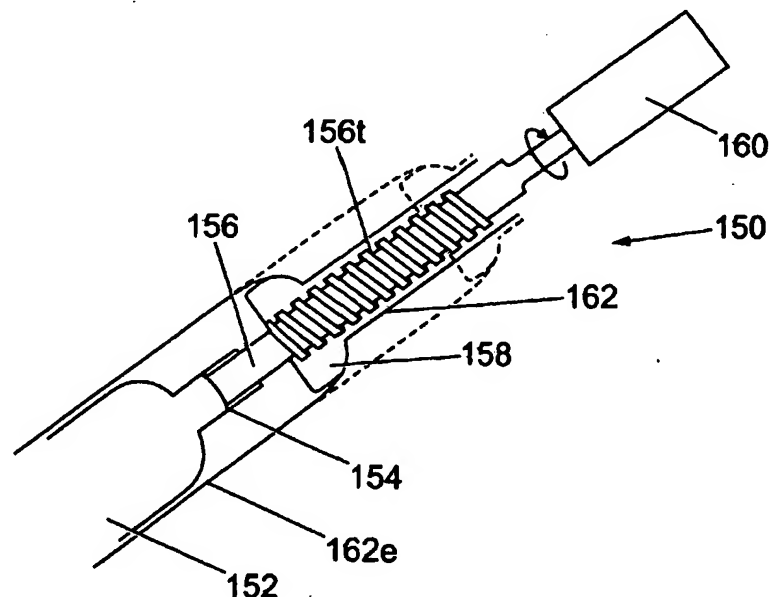
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[Continued on next page]

(54) Title: **APPARATUS FOR AND A METHOD OF EXPANDING TUBULARS**



(57) Abstract: Apparatus for and a method of expanding tubulars, and particularly tubulars or a string of tubulars that have one or more perforated portions and one or more non-perforated portions. In one embodiment, the apparatus (150) includes an inflatable element (e.g. a packer 152) that has a shaft (156) rotatably coupled thereto so that the shaft (156) can rotate relative to the inflatable element (152). An expansion cone (158) is threadably engaged with a threaded portion (156t) of the shaft (156) so that it moves along the threaded portion (156t) upon rotation of the shaft (156) relative to the cone (158).

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

1     "Apparatus for and a Method of Expanding Tubulars"

2

3     The present invention relates to apparatus for and a  
4     method of expanding tubulars, and particularly, but  
5     not exclusively, to tubulars that include a  
6     perforated or slotted portion and a non-perforated  
7     portion.

8

9     The invention can also be used with combination  
10    strings that include non-perforated tubulars and  
11    slotted or perforated tubulars that are coupled  
12    together to form a string.

13

14    Use of the term "tubulars" or "tubular members"  
15    herein will be understood to encompass any tubular  
16    or tubular member, such as casing, liner, drill pipe  
17    etc, and other such downhole tubulars.

18

19    It is known to expand tubular members to increase an  
20    outer diameter (OD) and/or an inner diameter (ID) of  
21    the tubular member. This can be done by radial  
22    expansion of the member, where a radial expansion

1 force is applied to a portion of the member to  
2 radially expand it. The radial expansion force is  
3 typically applied using an inflatable element, such  
4 as a packer.

5  
6 Alternatively, the tubular member can be expanded by  
7 applying a radial expansion force to the member so  
8 that it undergoes plastic and/or elastic  
9 deformation. In this case, the radial expansion  
10 force is typically applied using an expander device,  
11 e.g. an expansion cone, which is pushed or pulled  
12 through the tubular member. An OD of the expander  
13 device is typically the same as or slightly less  
14 than the final ID of the expanded tubular member.

15  
16 It will be appreciated that use of the terms "radial  
17 expansion" or "radially expanded" herein encompasses  
18 both of these options.

19  
20 The tubular members are typically used to line or  
21 case an open borehole, but have other uses as they  
22 can be used, for example, to repair damaged portions  
23 of casing or liner.

24  
25 The tubular members can include slotted or  
26 perforated portions where the slots or perforations  
27 expand into approximate diamond shapes or the like  
28 when the tubular member is radially expanded. The  
29 slotted or perforated portions can be used, for  
30 example, as a sand screen at or near a payzone of a  
31 formation or reservoir to prevent sand and other  
32 such contaminants from being mixed with hydrocarbons

1     that are recovered from the payzone or reservoir.  
2     The slotted or perforated portions can also be used  
3     to allow fluids from the payzone or formation to  
4     flow into the tubular member so that they can be  
5     recovered to the surface. Use of the term  
6     "perforated" herein is intended to encompass slots,  
7     apertures or the like in the tubular member.

8  
9     According to a first aspect of the present  
10    invention, there is provided apparatus for expanding  
11    a tubular member, the apparatus comprising an  
12    expander device that is capable of generating  
13    different radial expansion forces to expand  
14    respective portions of the tubular member.

15  
16    According to a second aspect of the present  
17    invention, there is provided a method of expanding a  
18    tubular member, the member including first and  
19    second portions, the method comprising the steps of  
20    running the tubular member into a borehole and  
21    radially expanding the first and second portions in  
22    the borehole using an expander device, wherein  
23    different radial expansion forces are exerted on the  
24    first and second portions respectively.

25  
26    The tubular member may have separate portions that  
27    are radially expandable to different extents.  
28    Typically, the respective portions comprise first  
29    and second portions. The first portion typically  
30    includes at least one perforated portion. The  
31    second portion typically includes at least one non-  
32    perforated portion. In most preferred embodiments,

1 the perforated portion can expand to a greater  
2 extent than the non-perforated portion. Typically,  
3 the radial expansion force required to expand the  
4 perforated portion is less than the radial expansion  
5 force required to expand the non-perforated portion.  
6 The tubular member may comprise a string of discrete  
7 members having perforated and non-perforated  
8 portions. The discrete members are typically  
9 coupled together by any conventional means, such as  
10 welding; screw threads etc.

11  
12 "Perforated" as used herein means that the member is  
13 provided with one or more apertures, slots or the  
14 like. Typically, a plurality of apertures or slots  
15 are provided. It will be appreciated that "non-  
16 perforated" as used herein means that the member  
17 does not have apertures or slots therein.

18  
19 One embodiment of an expander device comprises an  
20 inflatable element having a shaft rotatably attached  
21 thereto. The shaft can preferably rotate relative  
22 to the inflatable member. A bearing or the like is  
23 typically located between the inflatable element and  
24 the shaft. The inflatable member typically  
25 comprises a packer or the like. At least a portion  
26 of the shaft is provided with a screw thread. An  
27 expansion cone can be engaged with the screw thread  
28 on the shaft. The screw thread on the shaft is  
29 typically a low-pitch screw thread, but can be a  
30 high-pitch screw thread. The expansion cone is  
31 typically capable of longitudinal movement along the

1 screw thread when the shaft is rotated relative to  
2 the cone.

3  
4 The screw thread on the shaft can typically provide  
5 a gearing effect to the movement of the cone. A  
6 low-pitch screw thread provides for slower movement  
7 of the cone relative to the shaft, and can provide  
8 relatively high radial expansion forces but slower  
9 movement of the cone. A high-pitch screw thread  
10 provides for faster movement of the cone relative to  
11 the shaft, and can provide relatively lower  
12 expansion forces but faster movement of the cone.  
13 Thus, the pitch of the screw thread on the shaft can  
14 be selected to provide larger or smaller expansion  
15 forces as required.

16  
17 The inflatable element typically acts as an anchor  
18 for expansion of the perforated and/or non-  
19 perforated portions. Inflation of the inflatable  
20 element typically anchors the expander device at a  
21 lower end of the non-perforated portion, and can be  
22 used to isolate a pulling force that is typically  
23 applied to the expanded perforated portion during  
24 expansion of the non-perforated portion. The  
25 anchoring and isolation provided by the inflatable  
26 element substantially prevents the perforations in  
27 the pre-expanded perforated portion from collapsing  
28 during expansion of the non-perforated portions.

29  
30 The shaft is typically provided with attachment  
31 means (e.g. screw threads and/or a box or pin  
32 connection) to facilitate attaching the apparatus to

1 a drill string, coiled tubing string, wireline or  
2 the like. The drill string etc. can be used to  
3 rotate the shaft relative to the inflatable member.  
4 Optionally, the apparatus may include a motor or the  
5 like to rotate the shaft. It will be appreciated  
6 that a motor will not be required to rotate the  
7 shaft where it is coupled directly to a drill  
8 string. The motor typically comprises a mud motor  
9 where the shaft is coupled to a coiled tubing  
10 string.

11  
12 The shaft can be rotated in the opposite direction  
13 relative to the inflatable member to move the cone  
14 back down the shaft to its original starting  
15 position.

16  
17 Alternatively, or additionally, the cone is  
18 preferably provided with an engagement means that is  
19 capable of engaging the screw thread on the shaft.  
20 The cone is preferably provided with a release means  
21 that is used to release the engagement means from  
22 engagement with the screw thread on the shaft. The  
23 engagement means may comprise first and second  
24 portions that are provided with screw threads. The  
25 first and second portions are preferably capable of  
26 relative movement towards and/or away from one  
27 another. The release means may comprise a threaded  
28 rod or bolt that couples the first and second  
29 portions together. Rotation of the threaded rod or  
30 bolt in a first direction typically brings the first  
31 and second portions together, whereas rotation of  
32 the rod or bolt in a second direction, typically



1 opposite to the first, separates the two portions.  
2 Thus, the cone can be selectively engaged and  
3 disengaged from the screw thread provided on the  
4 shaft. The cone may include a motor or the like to  
5 rotate the threaded rod or bolt to move the portions  
6 towards or away from one another.

7  
8 The movement of the first and second portions can be  
9 hydraulically or otherwise controlled. For example,  
10 the release means may comprise a hydraulic cylinder  
11 that can be used to move the first and second  
12 portions towards and/or away from one another.

13  
14 Alternatively, the cone may be provided with a motor  
15 that rotates it in the opposite direction to move  
16 the cone to the opposite end of the screw thread  
17 (i.e. to return it to its original position).

18  
19 The release mechanism may comprise other mechanisms  
20 e.g. a self-releasing (high angle) or self-holding  
21 (small angle) taper such as a Morse Standard Taper  
22 Shank or collet-type release.

23  
24 The expansion cone may be steel or ceramic or a  
25 combination of these materials. The cone may also  
26 be of tungsten carbide. The cone is typically  
27 formed from a material that is harder than the  
28 member that it has to expand. It will be  
29 appreciated only the portions of the cone that  
30 contact that contact the member need be of or coated  
31 with the harder material.

32

1 The method typically includes the additional steps  
2 of providing an expander device comprising an  
3 inflatable element having a shaft rotatably attached  
4 thereto, wherein at least a portion of the shaft is  
5 provided with a screw thread, and an expansion cone  
6 that is engaged with the shaft.

7

8 The method typically includes the additional steps  
9 of attaching the expander device to a drill string,  
10 coiled tubing string or the like; and inflating the  
11 inflatable element to radially expand a portion of  
12 the tubular member into contact with a second  
13 conduit. The second conduit may be a casing, liner,  
14 a formation around the borehole or the like.

15

16 The method typically includes the additional steps  
17 of deflating the inflatable member and pulling or  
18 pushing the expander device through the tubular  
19 member to radially expand at least a portion thereof  
20 to increase its outer diameter and/or its inner  
21 diameter.

22

23 The method typically includes the additional steps  
24 of arresting the travel of the expander device when  
25 the cone reaches the non-perforated portion (or a  
26 relatively in-expansible portion) of the tubular  
27 member, inflating the inflatable member and rotating  
28 the shaft against the inflatable member. Rotation  
29 of the shaft typically causes the cone to move along  
30 the screw thread as it is held stationary by contact  
31 with an inner surface of the tubular member.

32

1 The method typically includes the additional steps  
2 of rotating the shaft in the opposite direction to  
3 move the cone back along the screw thread. This  
4 provides a means of returning the cone to its  
5 original starting position.

6  
7 The method typically includes the additional steps  
8 of releasing the engagement means to disengage the  
9 cone from the shaft and allowing the cone to travel  
10 back down the shaft.

11  
12 The method typically includes the additional steps  
13 of deflating the inflatable member and pulling or  
14 pushing the expander device through the tubular  
15 member to radially expand at least a portion thereof  
16 to increase its outer diameter and/or its inner  
17 diameter.

18  
19 Optionally, the expansion cone may be double-sided.  
20 In this embodiment, the expansion cone can be used  
21 to radially expand the tubular member in both the  
22 upward and downward directions. Use of the terms  
23 "upward" and "downward" will be understood to relate  
24 to a conventional vertical orientation of a  
25 borehole. It will be appreciated that the invention  
26 can also be used in deviated wells, and the terms  
27 "upward" and "downward" are to be construed  
28 accordingly, depending upon the orientation of the  
29 well. It will be appreciated that "downward"  
30 generally means away from the surface, and "upward"  
31 generally means towards the surface. Optionally  
32 also, the cone may comprise a plurality of fingers

1 that can be moved from a retracted to an expanded  
2 configuration.

3

4 A second embodiment of expander device comprises a  
5 rotary expansion mechanism and a solid expansion  
6 cone located therebelow. The solid expansion cone  
7 may be spaced-apart from the rotary expansion  
8 mechanism (e.g. by a shaft or the like) or can be  
9 integral therewith. The rotary expansion mechanism  
10 typically comprises a cage having a plurality of  
11 roller bearings attached thereto. The roller  
12 bearings are preferably inclined with respect to a  
13 longitudinal axis of the mechanism, typically at an  
14 angle of around  $20^\circ$ , so that they form an expansion  
15 cone on their outer surfaces. Other angles between  
16 around  $5^\circ$  and  $45^\circ$  can also be used, although angles  
17 outwith this range may also be used. However, the  
18 preferred angle is around  $20^\circ$ .

19

20 The solid expansion cone is typically of steel or  
21 ceramic, but can be a combination of these. The  
22 solid expansion cone may also be of tungsten  
23 carbide. The cone is typically of a material that  
24 is harder than that of the member that is has to  
25 expand. It will be appreciated only the portions of  
26 the cone that contact that contact the member need  
27 be of or coated with the harder material.

28

29 The rotary expansion mechanism may be rotated by  
30 rotating the drill string. Alternatively, or  
31 additionally, the rotary expansion mechanism may be  
32 rotated by passing fluid (e.g. drilling mud) over,

1 across or through the expansion mechanism. The  
2 roller bearings of the rotary expansion mechanism  
3 may be attached to a turbine blade that imparts a  
4 rotational force to the roller bearings when fluid  
5 passes through, over or across the blade.

6  
7 The method typically includes the additional steps  
8 of rotating the rotary expansion mechanism and  
9 pulling or pushing the apparatus through non-  
10 perforated portions of the tubular member to impart  
11 a radial expansion force thereto. The method  
12 typically includes the additional step of pushing or  
13 pulling the solid expansion cone through portions of  
14 the tubular member that are slotted or perforated.

15  
16 Optionally, the solid cone can be replaced with a  
17 second rotary expansion mechanism.

18  
19 Embodiments of the present invention shall now be  
20 described, by way of example only, with reference to  
21 the accompanying drawings, in which:-

22 Fig. 1 is a perspective view of a tubular  
23 member that includes non-perforated portions  
24 and a perforated portion;

25 Fig. 2 is a perspective view of an alternative  
26 tubular member that includes non-perforated  
27 portions and perforated portions;

28 Fig. 3 is part cross-sectional view a portion  
29 of a first embodiment of apparatus for  
30 expanding tubulars;

31 Fig. 4 is a cross-sectional view of a portion  
32 of a borehole;

1           Fig. 5 is a cross-sectional view of a stacked  
2           formation;

3           Fig. 6 is a cross-sectional view of a portion  
4           of a borehole similar to that of Fig. 4; and  
5           Fig. 7 is a part cross-sectional view of an  
6           alternative embodiment of apparatus for  
7           expanding tubulars.

8

9           Referring to the drawings, Fig. 1 shows a first  
10          embodiment of a tubular member 10 (e.g. a portion of  
11          casing, liner, drill pipe or other such member) that  
12          is used to line or case a borehole (not shown). Use  
13          of the term "tubular member" herein will be  
14          understood to encompass any tubular member, such as  
15          casing, liner, drill pipe etc.

16

17          Member 10 is preferably of a ductile material so  
18          that it is capable of being plastically and/or  
19          elastically deformed to expand an inner diameter  
20          (ID) and/or an outer diameter (OD) thereof.

21          Alternatively, or additionally, tubular member 10  
22          may also be capable of radial expansion under the  
23          application of a radial expansion force.

24

25          Member 10 includes a perforated or slotted portion  
26          12 that is approximately in a central portion of the  
27          member 10, and two non-perforated portions 14, 16,  
28          one on each side of the perforated portion 12. The  
29          non-perforated portions 14, 16 typically house  
30          attachment means (e.g. screw threads) that can be  
31          used to couple the member 10 into a string of other  
32          tubular members. The non-perforated portions 14, 16

1 provide a strong and reliable coupling between  
2 successive tubular members.

3

4 The perforated portion 12 is typically used as a  
5 sand screen at or near a payzone, a formation or a  
6 well. The perforated portion 12 can also be used to  
7 facilitate the recovery of hydrocarbons from the  
8 payzone, formation or well, as the slots or  
9 perforations allow the hydrocarbons to flow into the  
10 member 10 so that they can be recovered to the  
11 surface (not shown) in a conventional manner.

12

13 Fig. 2 shows an alternative tubular member 20  
14 (similar to tubular member 10) that is provided with  
15 two axially spaced-apart perforated portions 22, 24,  
16 with non-perforated portions 26, 28 at each end, and  
17 a further non-perforated portion 30 between the two  
18 perforated portions 22, 24.

19

20 Tubular members 10, 20 can be used for many  
21 different purposes, and are typically used in a  
22 string of similar or other tubular members (not  
23 shown). The string generally includes a number of  
24 tubular members that are non-perforated with one or  
25 more of the members 10, 20 or the like that have  
26 perforations.

27

28 For example and with reference to Fig. 4, there is  
29 shown a lower portion of a well or borehole that is  
30 provided with a casing 50 at a lower end thereof. A  
31 liner 52 (typically one or more non-perforated  
32 tubular members) is hung off the bottom of the

1 casing 50 in a conventional manner. The liner 52 is  
2 used to line a pre-drilled borehole 56 that extends  
3 towards a payzone, formation or well, indicated  
4 generally by 58, from which hydrocarbons can be  
5 recovered.

6  
7 The liner 52 is "tied back" to the casing 50 in a  
8 conventional manner and can be cemented into place  
9 by filling an annulus between the borehole 56 and an  
10 outer surface of the liner 52 with cement 54.

11 Thereafter, a perforated member 60 (which could be  
12 either member 10 (Fig. 1) or member 20 (Fig. 2) or  
13 the like) is inserted through casing 50 and liner 52  
14 so that an upper portion 60u of the member 60  
15 overlaps a lower portion 52l of the liner 52, and  
16 the member 60 is then radially expanded, as will be  
17 described.

18  
19 Referring to Fig. 5, there is shown a cross-  
20 sectional view of a portion of a stacked reservoir  
21 that typically has layers of different materials  
22 that require to be isolated from one another. For  
23 example, the stacked reservoir may have a lower  
24 shingle or shale layer 70, with a sand or reservoir  
25 layer 72 thereabove, a further shingle or shale  
26 layer 74 above the sand or reservoir layer 72, and a  
27 further sand or reservoir layer 76 below a third  
28 shingle or shale layer 78.

29  
30 The sand or reservoir layers 72, 76 typically  
31 facilitate the recovery of hydrocarbons from the  
32 surrounding formation that can be recovered to the



1 surface. In the example shown in Fig. 5, tubular  
2 member 20 (Fig. 2) can be used to line or case this  
3 particular portion of the stacked reservoir. The  
4 perforated portions 22, 24 are axially aligned with  
5 the sand layers 72, 76. The non-perforated portions  
6 26, 30, 28 are axially aligned with the shale layers  
7 70, 74, 78 respectively, so that they isolate the  
8 shale layers 70, 74, 78, whereas the perforated  
9 portions 22, 24 act as a sand screen and allow  
10 hydrocarbons recovered from the sand or reservoir  
11 layers 72, 76 to be recovered to the surface.

12

13 Fig. 6 shows a lower portion of a borehole that is  
14 similar to that shown in Fig. 4. A casing 80 is  
15 provided at a lower end of the borehole that  
16 typically forms a string of such casings that  
17 prevent the formation surrounding the borehole from  
18 collapsing, and also facilitates the recovery of  
19 hydrocarbons to the surface. A liner 82 (e.g. one  
20 or more non-perforated tubular members) is hung off  
21 the bottom of the casing 80 in a conventional  
22 manner. The liner 82 is typically cemented into  
23 place by filling an annulus between the borehole  
24 (not shown) and an outer surface of the liner 82  
25 with cement 84.

26

27 A perforated or slotted member 86 (e.g. member 20  
28 (Fig. 2)) is attached at a lower end of the liner  
29 82. The perforated member 86 is tied back to the  
30 liner 82 by overlapping the liner 82 and the member  
31 86 so that when the member 86 is radially expanded,  
32 an outer surface of the member 86 contacts an inner

1 surface of the liner 82 to create a junction and a  
2 seal, generally designated at 88.

3

4 As with Fig. 5, a lower end of the horizontal  
5 borehole has a number of different portions, similar  
6 to the stacked reservoir of Fig. 5 but in a  
7 generally horizontal configuration. The borehole of  
8 Fig. 6 has a first portion 90 from which  
9 hydrocarbons may be recovered; a second portion 92  
10 from which hydrocarbons cannot be recovered (e.g.  
11 shale, shingle or the like); a third portion 94 from  
12 which hydrocarbons may be recovered; a fourth  
13 portion 96 from which hydrocarbons cannot be  
14 recovered; and a fifth portion 98 from which  
15 hydrocarbons may be recovered.

16

17 A combination of non-perforated and perforated  
18 tubular members can be used to line the borehole.  
19 In this particular example, the combination  
20 comprises perforated portions 102, 106, 110 at the  
21 (hydrocarbon producing) portions 90, 94, 98 and non-  
22 perforated portions 104, 108 at the non-hydrocarbon  
23 producing portion 92, 96.

24

25 It will be appreciated that the perforated portions  
26 102, 106, 110 of member 86 may comprise tubular  
27 members 10 (Fig. 1) that have been coupled to non-  
28 perforated tubulars (e.g. lightweight pipe) 104, 108  
29 using screw threads for example. Alternatively, the  
30 various portions may comprise a single length with  
31 alternate non-perforated and perforated portions,  
32 similar to member 20 (Fig. 2).

1  
2 The hydrocarbon producing portions 90, 94, 98 allow  
3 hydrocarbons to flow into the combination of non-  
4 perforated and perforated tubular members (i.e.  
5 member 86), into the member 86 and thus they can be  
6 recovered to the surface.

7  
8 It will be noted that the members 10, 20, 60, 86 and  
9 other combinations of non-perforated and perforated  
10 tubular members can be difficult to expand radially  
11 because the members include perforated portions and  
12 non-perforated portions. The expansion force  
13 required to radially expand perforated portions is  
14 significantly less than that required to expand non-  
15 perforated portions. The higher force exerted on  
16 the non-perforated portion can collapse the expanded  
17 perforated tubular that is coupled to the non-  
18 perforated portion, because the very high force on  
19 the non-perforated portion can pull or stretch the  
20 perforated portion so that it collapses radially and  
21 the perforations close up.

22  
23 Note that the radial expansion of the members is  
24 typically achieved by expanding the member "bottom-  
25 up"; that is, the expander device that is used to  
26 impart a radial expansion force is pushed or pulled  
27 upwardly through the member from the lowest part to  
28 be expanded. However, the member can also be  
29 expanded top-down, provided that sufficient force  
30 can be applied to the expander device by slacking  
31 off weight above the device, or hanging off  
32 sufficient weight below the expander device.

1  
2 Fig. 3 shows a first embodiment of apparatus 150 for  
3 expanding tubulars, in this embodiment the tubular  
4 is a combination string of perforated and non-  
5 perforated tubulars.

6  
7 Apparatus 150 includes an inflatable element, such  
8 as a packer 152 that is located at a lower end of  
9 the apparatus 150. A bearing 154, such as a thrust  
10 bearing, is located above the packer 152 and has a  
11 shaft 156 rotatably attached to it. The bearing 154  
12 allows the shaft 156 to rotate whilst the packer 152  
13 remains stationary. Shaft 156 is part threaded,  
14 preferably with a relatively low-pitch screw thread  
15 156t, and an expansion cone 158 engages with the  
16 screw thread 156t on the shaft 156, the cone 158  
17 being capable of longitudinal movement up and down  
18 the threaded portion of the shaft 156. A drive  
19 means 160 (e.g. a motor or the like) for rotating  
20 the shaft 156 is optionally provided at an upper end  
21 of the shaft 156. An upper end of the drive means  
22 160 is typically attached to a drill string, coiled  
23 tubing string or the like.

24  
25 It will be appreciated that the drive means 160 may  
26 not be required where the shaft 156 is coupled  
27 directly to a drill string, as the string can be  
28 rotated in a conventional manner to rotate the shaft  
29 156. In this case, the shaft 156 would be provided  
30 with attachment means (e.g. screw threads) so that  
31 it can be attached to the drill string.

32

1 In use, the apparatus 150 is located in a liner 162,  
2 casing or the like that is to be radially expanded  
3 to increase its outer diameter (OD) and/or inner  
4 diameter (ID). The packer 152 and the expansion  
5 cone 158 are located in a pre-expanded portion 162e  
6 of the liner 162 before the liner 162 is run into  
7 the borehole to the required depth. The pre-  
8 expanded portion 162e is typically sufficiently  
9 expanded to allow the packer 152 to be located  
10 therein, but is generally not fully expanded so that  
11 the liner 162 can be run into the borehole.

12

13 Once at the required depth, the packer 152 is  
14 inflated using any conventional means to expand the  
15 pre-expanded portion 162e radially outwards so that  
16 an outer surface of the pre-expanded portion 162e  
17 contacts an inner surface of a second conduit. The  
18 second conduit may be an uncased formation, pre-  
19 installed casing, liner, or the like. The further  
20 expansion of the pre-expanded portion 162e can act  
21 as an anchor for the liner 162 as it is radially  
22 expanded by the cone 158.

23

24 Optionally, the packer 152 may be deflated and moved  
25 within the liner 162, where it is re-inflated to  
26 radially expand the liner 162 into contact with the  
27 second conduit. The additional expansion of the  
28 liner 162 serves to increase the surface area of the  
29 outer surface of the liner 162 that acts as an  
30 anchor.

31

1 The packer 152 is then deflated and the cone 158 is  
2 pulled through the liner 162 to radially expand the  
3 liner 162 in a known manner. The cone 158 may be  
4 pulled through the liner 162 using the drill string,  
5 coiled tubing string or the like to which it is  
6 attached. When the cone 158 reaches a non-  
7 perforated portion of the liner 162, this will be  
8 indicated by an increase in the force required to  
9 expand the liner 162. At this point, the packer 152  
10 is re-inflated to act as an anchor for the apparatus  
11 150. Thereafter, the shaft 156 is rotated by  
12 actuation of the motor 160, or by rotation of the  
13 drill string to which shaft 156 is attached. The  
14 shaft 156 is thus rotated against the packer 152  
15 using the bearing 154.

16

17 It will be appreciated that the packer 152 can be  
18 detached from the shaft 156 and left at the lower  
19 end of the liner 162 to act as an anchor during  
20 expansion of the liner 162. When the cone 158  
21 reaches a non-perforated portion, the cone 158 and  
22 shaft 156 are lowered until the packer 152 engages  
23 the shaft 156, and the apparatus 150 returned to the  
24 non-perforated portion, where the packer 152 is re-  
25 inflated.

26

27 The cone 158 is located on the low-pitch screw  
28 thread 156t on the shaft 156 and is prevented from  
29 rotating with the shaft 156 by friction on its OD  
30 where the cone 158 contacts the liner 162. As the  
31 cone 158 is prevented from rotating by contact with  
32 the liner 162, it will move up the screw thread on

1 shaft 156 as the shaft 156 rotates, and thus expand  
2 the liner 162 over the non-perforated portion.

3

4 It will be appreciated that it is preferable to have  
5 the length of the portion of the shaft 156 that is  
6 provided with the screw thread 156t at least as long  
7 as the non-perforated portion of the liner 162. It  
8 is preferable to have the length of the screw thread  
9 156t slightly longer than that required to expand  
10 the non-perforated portion. The packer 152 acts as  
11 both an anchor for the expansion of the non-  
12 perforated portion and can also help prevent the  
13 expanded perforated portion therebelow from  
14 collapsing by keeping it open against the induced  
15 collapsing force.

16

17 Once the cone 158 has travelled the length of the  
18 screw thread 156t, the shaft 156 can be rotated in  
19 the opposite direction or the force preventing the  
20 cone 158 from rotating is removed, allowing the cone  
21 158 to travel back down the screw thread 156t to its  
22 original starting position.

23

24 The cone 158 can typically be provided with at least  
25 a portion of screw thread that interengages with the  
26 thread 156t on the shaft 156. The thread on the  
27 cone 158 could be provided on two or more segments  
28 that are capable of being moved towards and away  
29 from one another. For example, two portions may be  
30 coupled using a threaded shaft (e.g. a bolt) that  
31 can be rotated to move the two portions towards and  
32 away from one another. One of the portions could be

1 provided with a threaded nut that interengages with  
2 the threads on the bolt. The threaded bolt may also  
3 be provided with a quick-release mechanism, such as  
4 a lever that is moved to disengage the nut from the  
5 bolt. This arrangement is similar to that used in a  
6 common bench vice.

7

8 In use, the bolt may be driven by a motor located  
9 within or as part of the cone 158. Rotation of the  
10 bolt in a first direction would draw the two  
11 portions together and thus the cone 158 would be  
12 threadedly engaged with the shaft 156. Rotation of  
13 the bolt in a second direction, typically opposite  
14 to the first direction, would move the two portions  
15 away from one another, thus releasing the cone 158  
16 from the shaft 156 and allowing it to travel back to  
17 its original starting position without rotation  
18 (e.g. under the force of gravity or as the shaft 156  
19 is pulled out of the borehole).

20

21 Alternatively, the two portions may be coupled using  
22 a hydraulic cylinder or the like that can be  
23 actuated and de-actuated to move the portions  
24 towards and away from one another.

25

26 As a further alternative, other release mechanisms  
27 could be used including a self-releasing (high  
28 angle) or self-holding (small angle) taper such as a  
29 Morse Standard Taper Shank or collet-type release.

30

31 With the cone 158 back in its original position, it  
32 can be pulled through the perforated portion until a



1 non-perforated portion is reached, whereupon the  
2 packer 152 is then inflated and the shaft 156  
3 rotated to move the cone 158 through the liner to  
4 expand it, as previously described.

5  
6 The cone 158 may be double-sided, that is, the cone  
7 158 can be provided with a face that can be used to  
8 expand the liner or the like in both upward and  
9 downward directions. Also, two packers 152 could be  
10 used; one that travels with the cone 158 as  
11 described above, and a second that is used to anchor  
12 the liner 162 at a lower end thereof continuously  
13 whilst the remainder of the liner 162 is radially  
14 expanded, as described above.

15  
16 It would be advantageous to have a segmented cone  
17 that is provided with a plurality of fingers that  
18 are capable of being moved from a retracted  
19 configuration to an expanded configuration. Outer  
20 surfaces of the fingers can provide one or more  
21 expansion cones so that when the fingers are in the  
22 expanded position, the cone can be used to radially  
23 expand the liner 162. However, the cone can be run  
24 into the borehole, liner etc in a collapsed state  
25 (i.e. with the fingers retracted). This is  
26 advantageous as the liner 162 need not be provided  
27 with a pre-expanded portion 162e, and the apparatus  
28 150 can be run into a liner that has previously been  
29 located in the borehole. The fingers of the cone  
30 can then be moved to the radially expanded position  
31 so that the liner or the like can be expanded.

32

1 It will be noted that where an expandable cone is  
2 used, the packer 152 can be used to inflate a lower  
3 portion of the liner 162 (i.e. at the pre-expanded  
4 portion 162e) to provide an anchor for the liner  
5 162. Thereafter, the packer 152 is deflated and  
6 moved upwardly to a second position, above the  
7 first, and inflated again. The second expanded  
8 portion of liner 162 facilitates opening of the  
9 fingers of the cone more easily into the expanded  
10 configuration.

11

12 Referring to Fig. 7, there is shown an alternative  
13 apparatus 200 for the radial expansion of a mixed  
14 string of perforated and non-perforated tubulars.

15

16 Apparatus 200 is particularly suited for use when  
17 expanding portions of non-perforated tubular 202 and  
18 perforated or slotted tubular 204. It will be  
19 generally appreciated that tubulars 202, 204 may be  
20 casing, liner or the like. It will also be  
21 appreciated that tubular 202, 204 may comprise a  
22 plurality of discrete lengths of tubular member that  
23 are coupled together (e.g. by welding or screw  
24 threads).

25

26 Apparatus 200 includes a rotary expansion mechanism  
27 206 that typically comprises a cage 208 having a  
28 number of roller bearings 210 attached thereto. The  
29 roller bearings 210 are inclined (typically at  
30 around 20° with respect to a longitudinal axis of  
31 the apparatus 200) so that they form an expansion  
32 cone on their outer surfaces. Other angles between

1 around 5° and 45° can also be used, although angles  
2 outwith this range may also be used. However, the  
3 preferred angle is around 20°.

4  
5 The rotary expansion mechanism 206 is primarily used  
6 to transmit radial and pull force into a radial  
7 expansion force, instead of only pull force. Thus,  
8 the rotary expansion mechanism 206 has the advantage  
9 of reducing friction.

10  
11 An upper portion of the rotary expansion mechanism  
12 206 is typically provided with attachment means (not  
13 shown) such as screw threads or the like to enable  
14 the apparatus 200 to be attached to a drill string,  
15 coiled tubing string or the like.

16  
17 A solid expansion cone 212 is attached below the  
18 rotary expansion mechanism 206, typically via a  
19 shaft 214 or the like. It will be understood that  
20 the solid expansion cone 212 may be integral with  
21 the rotary expansion mechanism 206. The solid  
22 expansion cone 212 is typically of steel or ceramic,  
23 but may be a combination of steel and ceramic,  
24 although it may also be made of tungsten carbide or  
25 the like. The solid expansion cone 212 is typically  
26 of a material that is harder than the member that it  
27 has to expand. As before, only the portion of the  
28 cone 212 that come into contact with the tubulars  
29 202, 204 need be of or coated with the harder  
30 material.

31

1     The perforated or slotted tubular 202 is provided  
2     with a pre-expanded portion 202e in which a portion  
3     of the apparatus 200 (typically the solid expansion  
4     cone 212) is located. Similarly, the non-perforated  
5     tubular 204 is provided with a pre-expanded portion  
6     204e that is attached to pre-expanded portion 202e  
7     in use. Tubulars 202 and 204 can be coupled  
8     together using any conventional means, such as screw  
9     threads or the like. Conventional pin and box  
10    connections may be used, for example.

11  
12    In use, the slotted or perforated tubular 202 is  
13    lowered into the borehole (not shown) to the  
14    required depth, and may be held in place using any  
15    conventional means (e.g. a packer or the like) if  
16    required. Thereafter, the apparatus 200 is attached  
17    to a string 216 of drill pipe or the like that forms  
18    a conventional drill string. The apparatus 200 is  
19    attached to the drill string 216 using any  
20    conventional means. It will be appreciated that  
21    apparatus 200 could also be attached to a coiled  
22    tubing string or the like.

23  
24    The drill string 216 with the apparatus 200 attached  
25    thereto is then lowered into the borehole until the  
26    solid expansion cone 212 is located within the pre-  
27    expanded portion 202e of the perforated or slotted  
28    tubular 202. The non-perforated tubular 204 is then  
29    lowered into the borehole and the pre-expanded  
30    portion 204e is threadedly engaged with the pre-  
31    expanded portion 202e of the perforated or slotted  
32    tubular 202.

1  
2 It will be appreciated that the apparatus 200 can be  
3 located in the pre-expanded portions 202e, 204e and  
4 the tubulars 202, 204 threadedly coupled at the  
5 surface so that the entire assembly can be lowered  
6 into the borehole.

7  
8 The rotary expansion mechanism 206 is then rotated,  
9 typically by rotating the drill string 216. Where  
10 the apparatus 200 is coupled to a coiled tubing  
11 string, a mud motor or the like (not shown)  
12 typically forms part of the string and can be used  
13 to rotate the apparatus 200 by actuation of the  
14 motor. The rotary expansion mechanism 206 may also  
15 be rotated by the flow of drilling fluid (e.g. mud)  
16 through, over or across the mechanism 206. For  
17 example, the rotary expansion mechanism 206 may be  
18 provided with a turbine blade (not shown) that is  
19 coupled to the rotary bearings 210 so that drilling  
20 fluid that passes over the turbine blades imparts a  
21 rotational force to the rotary bearings 210.

22  
23 As the rotary expansion mechanism 206 is rotated, it  
24 is pulled upwards through the non-perforated tubular  
25 204 to radially expand it. The inclination of the  
26 roller bearings 210 of the rotary expansion  
27 mechanism 206 provides an expansion force that  
28 causes a radial plastic deformation of the non-  
29 perforated tubular 204 to radially expand its outer  
30 diameter and/or its inner diameter. It will be  
31 appreciated that use of the term "radial plastic  
32 deformation" is understood to be the use of an

1 expander device (e.g. the rotary expansion mechanism  
2 206 or cone 212) that is pushed or pulled through  
3 the tubular 204 to impart a radial expansion force  
4 to the tubular 204 so that both the ID and the OD of  
5 the tubular 204 increases.

6  
7 Once the non-perforated tubular 204 has been  
8 completely expanded, the drill string 216 is then  
9 lowered until the solid cone 212 contacts the  
10 perforated or slotted tubular 202. The cone 212 is  
11 then forced through the perforated or slotted  
12 tubular 202 by, for example, slacking off weight  
13 above the apparatus 200 so that the weight of the  
14 string 216 and the apparatus 200 is used to push  
15 down on the cone 212. In this way, the tubular 202  
16 is radially expanded to increase its OD and its ID.

17  
18 It will be appreciated that the drill string 216 may  
19 be rotated, or the apparatus 200 otherwise rotated,  
20 so that the cone 212 rotates during use.

21  
22 After the perforated or slotted tubular 202 has been  
23 expanded, the drill string 216 and the apparatus 200  
24 is then removed from the borehole in the  
25 conventional manner (e.g. it is pulled out of hole).

26  
27 It will be appreciated that the solid cone 212 can  
28 be replaced with another rotary expansion mechanism  
29 206 that can be used to expand the slotted or  
30 perforated tubular 202. Where the combination  
31 string comprises a single length of non-perforated  
32 tubular above a single length of perforated or

1     slotted tubular, the rotary expansion mechanism 206  
2     can be used for upward expansion of the non-  
3     perforated tubular, and a solid cone 212 used for  
4     the downward expansion of the perforated or non-  
5     perforated tubular. Alternatively, a solid cone  
6     (e.g. cone 212) can be used to expand both. For  
7     multiple lengths of non-perforated and perforated or  
8     slotted tubular, it is preferable to use a rotary  
9     expansion mechanism 206 for expansion in both the  
10    upward and downward directions.

11

12    It is possible that expanding a slotted tubular that  
13    has non-perforated portions can be done with the  
14    member in compression. The slotted portion can be  
15    expanded in this situation and it is possible that  
16    the expansion force could increase by a factor of 10  
17    or more at the non-perforated portions without  
18    damaging the expanded perforated portion.

19

20    Certain embodiments of the apparatus and method  
21    allow the radial expansion of a combination string  
22    of both perforated or slotted tubulars. Certain  
23    embodiments also allow the combination string to be  
24    radially expanded in only a single pass of the  
25    apparatus through the combination string, thus  
26    providing significant savings in terms of costs and  
27    rig time.

28

29    Modifications and improvements may be made to the  
30    foregoing without departing from the scope of the  
31    present invention.

32

1     CLAIMS

2

3     1.   Apparatus for expanding a tubular member  
4     comprising an expander device (150, 200) that is  
5     capable of generating different radial expansion  
6     forces to expand respective portions (12, 14, 16,  
7     22, 24, 26, 28, 30, 102, 104, 106, 108, 110) of the  
8     tubular member (10, 20, 60, 86, 162, 202, 204).

9

10    2.   Apparatus according to claim 1, wherein the  
11    expander device (150, 200) includes an expansion  
12    cone (158, 206, 212).

13

14    3.   Apparatus according to claim 2, wherein the  
15    expander device (150) further includes an inflatable  
16    element (152) having a shaft (156) rotatably  
17    attached thereto.

18

19    4.   Apparatus according to claim 3, wherein the  
20    shaft (156) can rotate relative to the inflatable  
21    member (152).

22

23    5.   Apparatus according to claim 3 or claim 4,  
24    wherein the inflatable member comprises a packer  
25    (152).

26

27    6.   Apparatus according to any one of claims 3 to  
28    5, wherein at least a portion of the shaft (156) is  
29    provided with a screw thread (156t).

30



1 7. Apparatus according to claim 6, wherein the  
2 expansion cone (158) can engage the screw thread  
3 (156t) on the shaft (156).  
4

5 8. Apparatus according to claim 7, wherein the  
6 screw thread (156t) on the shaft (156) is a low-  
7 pitch screw thread (156t).  
8

9 9. Apparatus according to claim 7 or claim 8,  
10 wherein the expansion cone (158) is capable of  
11 longitudinal movement along the screw thread (156t)  
12 when the shaft (156) is rotated relative to the cone  
13 (158).  
14

15 10. Apparatus according to any one of claims 3 to  
16 9, wherein the inflatable element (152) acts as an  
17 anchor for expansion of perforated and/or non-  
18 perforated portions (12, 14, 16, 22, 24, 26, 28, 30,  
19 102, 104, 106, 108, 110) of the tubular member (10,  
20 20, 60, 86, 162, 202, 204).  
21

22 11. Apparatus according to any one of claims 3 to  
23 10, wherein the inflatable element (152) isolates a  
24 pulling force applied to an expanded perforated  
25 portion (12, 22, 24, 102, 106, 110) during expansion  
26 of a non-perforated portion (14, 16, 26, 28, 30,  
27 104, 108) of the tubular member (10, 20, 60, 86,  
28 162, 202, 204).  
29

30 12. Apparatus according to claim 1, wherein the  
31 expander device (200) comprises a rotary expansion

1 mechanism (206) and a solid expansion cone (212)  
2 attached thereto.

3

4 13. Apparatus according to claim 12, wherein the  
5 rotary expansion mechanism (206) comprises a cage  
6 (208) having a plurality of roller bearings (210)  
7 attached thereto.

8

9 14. Apparatus according to claim 13, wherein the  
10 roller bearings (210) are inclined with respect to a  
11 longitudinal axis of the mechanism (206) so that  
12 they form an expansion cone on their outer surfaces.

13

14 15. Apparatus according to claim 14, wherein the  
15 roller bearings (210) are inclined at an angle of  
16 around 20°.

17

18 16. Apparatus according to any one of claims 12 to  
19 15, wherein the rotary expansion mechanism (206) is  
20 rotatable.

21

22 17. Apparatus according to claim 16, wherein the  
23 rotary expansion mechanism (206) is rotatable by  
24 rotating a drill string (216), or by passing fluid  
25 over, across or through the expansion mechanism  
26 (206).

27

28 18. Apparatus according to any preceding claim,  
29 wherein the respective portions comprise first and  
30 second portions (12, 14, 16, 22, 24, 26, 28, 30,  
31 102, 104, 106, 108, 110).

32

1 19. Apparatus according to claim 18, wherein the  
2 first portion includes at least one perforated  
3 portion (12, 22, 24, 102, 106, 110), and the second  
4 portion includes at least one non-perforated portion  
5 (14, 16, 26, 28, 30, 104, 108).

6  
7 20. Apparatus according to any preceding claim,  
8 wherein the tubular member (10, 20, 60, 86, 162,  
9 202, 204) comprises a string of discrete members  
10 having perforated (12, 22, 24, 102, 106, 110) and  
11 non-perforated portions (14, 16, 26, 28, 30, 104,  
12 108).

13  
14 21. A method of expanding a tubular member, the  
15 member including first and second portions (12, 14,  
16 16, 22, 24, 26, 28, 30, 102, 104, 106, 108, 110),  
17 the method comprising the steps of running the  
18 tubular member (10, 20, 60, 86, 162, 202, 204) into  
19 a borehole and radially expanding the first and  
20 second portions (12, 14, 16, 22, 24, 26, 28, 30,  
21 102, 104, 106, 108, 110) in the borehole using an  
22 expander device (150, 200), wherein different radial  
23 expansion forces are exerted on the first and second  
24 portions (12, 14, 16, 22, 24, 26, 28, 30, 102, 104,  
25 106, 108, 110) respectively.

26  
27 22. A method according to claim 21, wherein the  
28 method includes the additional step of providing an  
29 expander device (150) comprising an inflatable  
30 element (152) having a shaft (156) rotatably  
31 attached thereto, wherein at least a portion of the  
32 shaft (156) is provided with a screw thread (156t),

1 and an expansion cone (158) that is engaged with the  
2 shaft (156).  
3

4 23. A method according to claim 22, wherein the  
5 method includes the additional steps of attaching  
6 the expander device (150) to a drill string or  
7 coiled tubing string, and inflating the inflatable  
8 element (156) to radially expand a portion (162e) of  
9 the tubular member (162) into contact with a second  
10 conduit.  
11

12 24. A method according to claim 23, wherein the  
13 method includes the additional steps of deflating  
14 the inflatable member (152) and pulling or pushing  
15 the expander device (158) through the tubular member  
16 (162) to radially expand at least a portion thereof  
17 to increase its outer diameter and/or its inner  
18 diameter.  
19

20 25. A method according to claim 24, wherein the  
21 first portion comprises one or more perforated  
22 portions (12, 22, 24, 102, 106, 110), the second  
23 portion comprises one or more non-perforated  
24 portions (14, 16, 26, 28, 30, 104, 108), and the  
25 method includes the additional steps of arresting  
26 the travel of the expander device when the cone  
27 reaches the second portion (14, 16, 26, 28, 30, 104,  
28 108) of the tubular member (162), inflating the  
29 inflatable member (152) and rotating the shaft (156)  
30 against the inflatable member (152).  
31

1     26. A method according to claim 25, wherein  
2     rotation of the shaft (152) causes the cone (158) to  
3     move along the screw thread (156t) as it is held  
4     stationary by contact with an inner surface of the  
5     tubular member (162).

6  
7     27. A method according to claim 25 or claim 26,  
8     wherein the method includes the additional step of  
9     rotating the shaft (156) in the opposite direction  
10    to move the cone (158) back along the screw thread  
11    (156t).

12  
13    28. A method according to claim 27, wherein the  
14    method includes the additional steps of deflating  
15    the inflatable member (156) and pulling or pushing  
16    the expander device (150) through the tubular member  
17    (152) to radially expand at least a portion thereof  
18    to increase its outer diameter and/or its inner  
19    diameter.

20  
21    29. A method according to claim 21, wherein the  
22    method typically the additional steps of providing  
23    an expander device (200) comprising a rotary  
24    expansion mechanism (206) and a solid expansion cone  
25    (212).

26  
27    30. A method according to claim 29, wherein a first  
28    tubular member (202) includes one or more perforated  
29    portions, a second tubular member (204) includes one  
30    or more non-perforated portions, and the method  
31    includes the additional steps of rotating the rotary  
32    expansion mechanism (206) and pulling or pushing the

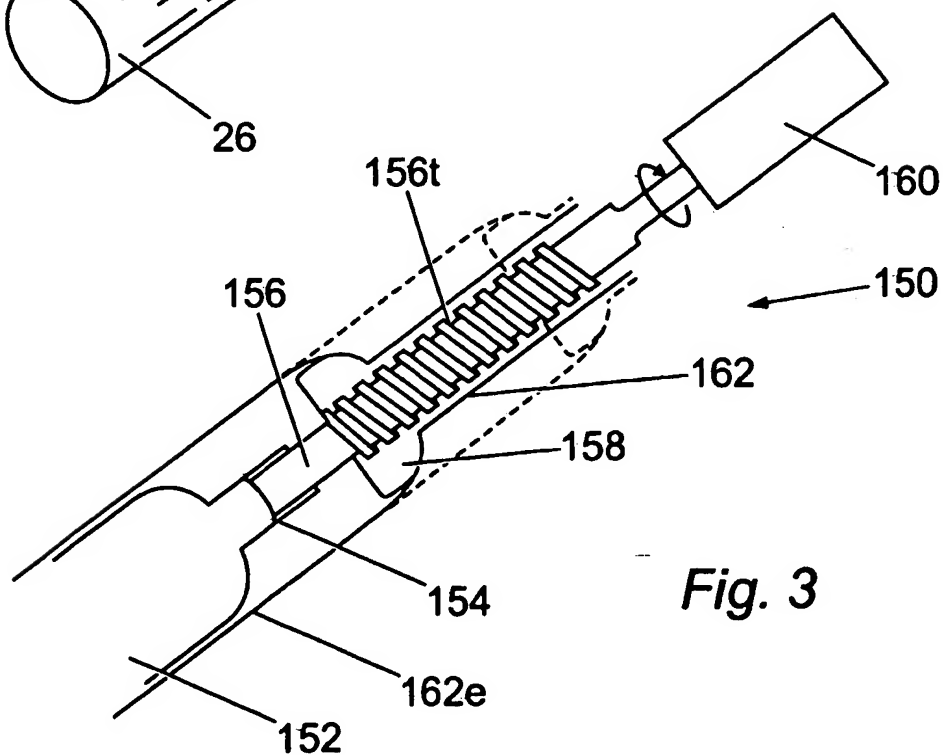
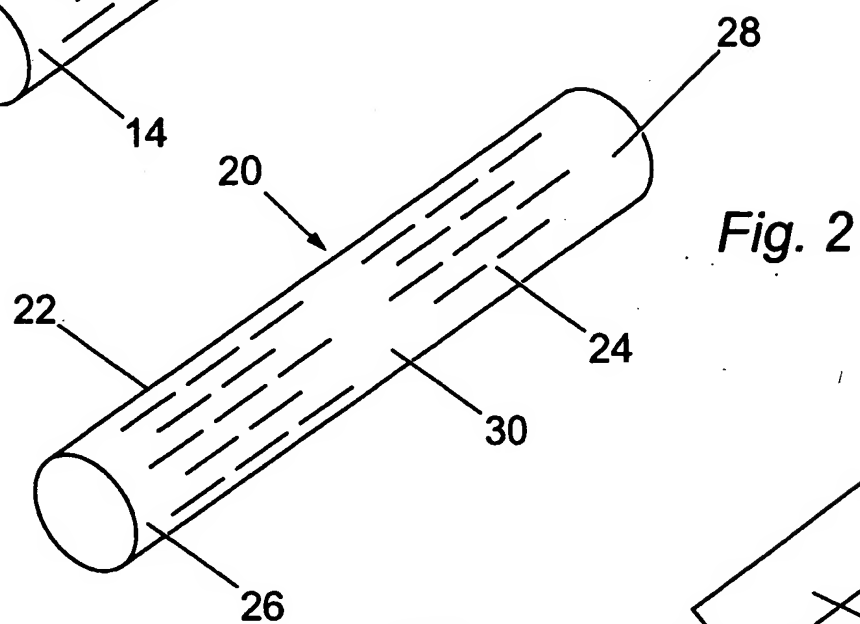
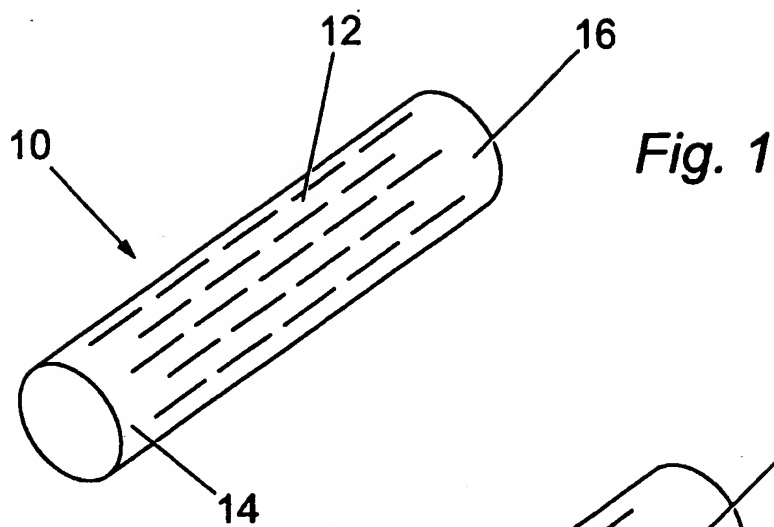
1 device (200) through the second tubular (204) to  
2 impart a radial expansion force thereto.

3

4 31. A method according to claim 30, wherein the  
5 method includes the additional step of pushing or  
6 pulling the solid expansion cone (212) through the  
7 second tubular member (202).

8

1 / 4



2 / 4

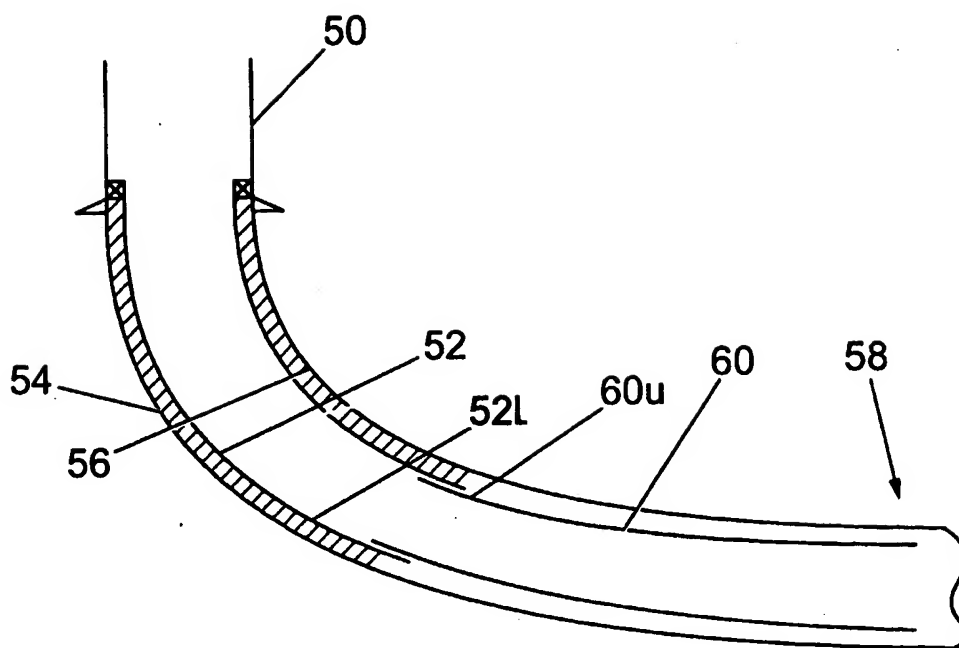


Fig. 4

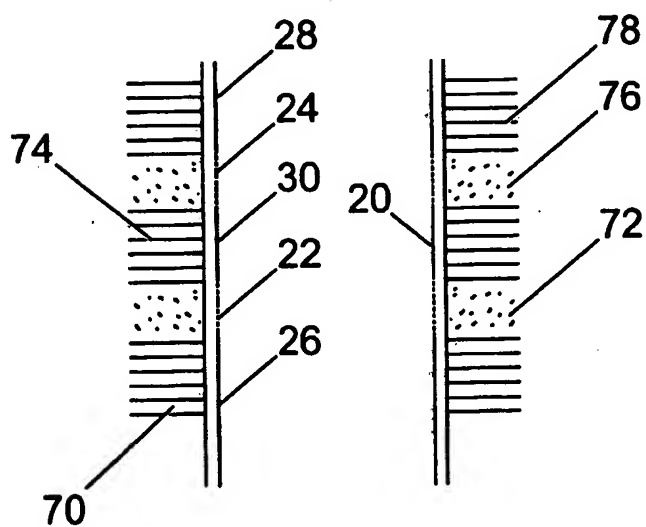


Fig. 5



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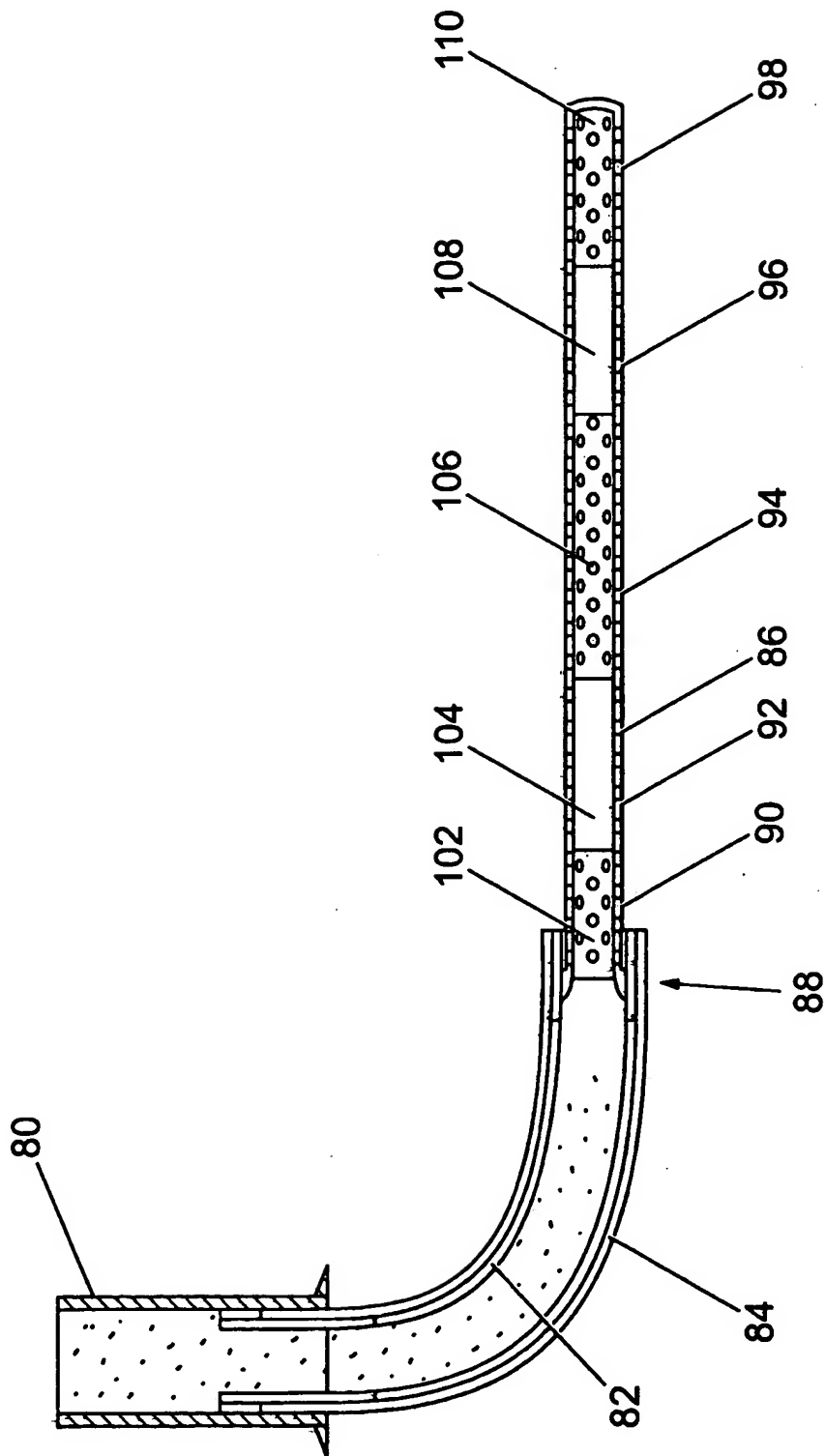
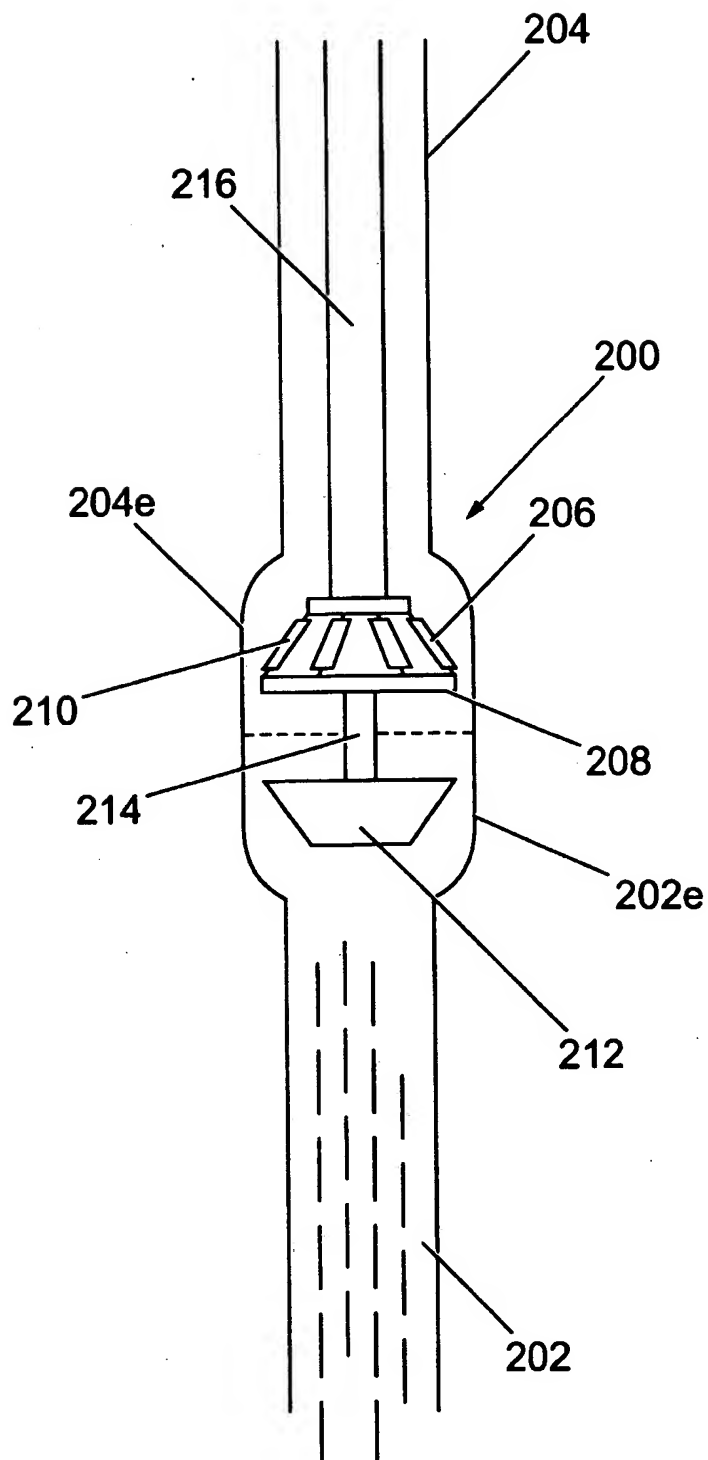


Fig. 6

4 / 4



*Fig. 7*

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 02/03734

A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 7 B21D39/20 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B21D E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 986 383 A (PETTEYS HOWARD A) 19 October 1976 (1976-10-19)	1-4, 6-10, 12, 18-20
A	abstract; figures	5, 21, 22
X	FR 1 142 975 A (SZEBO LASZLO) 25 September 1957 (1957-09-25)	1, 2, 12-16, 18-20
A	figures	3, 4, 6, 10
X	US 4 580 426 A (ZAFRED PAOLO R) 8 April 1986 (1986-04-08) abstract; figures column 15, line 23 - column 16, line 40	1, 2, 12-16
X	US 2 096 234 A (ERWIN WELDON C) 19 October 1937 (1937-10-19) page 2, line 51-73	1, 2, 21, 29
	-/-	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search

5 November 2002

Date of mailing of the international search report

15/11/2002

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 02/03734

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 18354 A (E2TECH LTD; OOSTERLING PETER) 15 March 2001 (2001-03-15)	1,2,21
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# INTERNATIONAL SEARCH REPORT

information on patent family members

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